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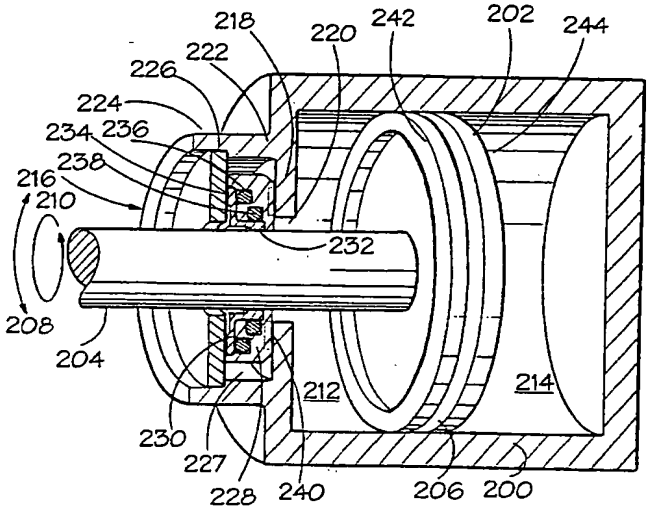
(54) Title: HYDRAULIC ACTUATOR AND CONTINUOUSLY VARIABLE RATIO TRANSMISSION UNIT



(57) Abstract: A hydraulic actuator is disclosed which is double-acting and in which a seal is formed, where an elongate piston rod (204) emerges from an end of the actuator's cylinder (200), which allows for angular displacement of the piston rod about a transverse axis. A sealing arrangement is utilised comprising a seal body (240) through which the piston rod passes, the seal body being located between walls (218, 226) of an inwardly open annular recess (227) and being capable of radial movement in order to accommodate angular displacement of the piston rod. The seal body carries a sealing band (230) having first and second sealing surfaces respectively resiliently biased against the piston rod and one of the walls of the annular recess, thereby to form a pair of seals which together resist egress of fluid from the end of the cylinder.

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DESCRIPTION

HYDRAULIC ACTUATOR AND CONTINUOUSLY VARIABLE RATIO TRANSMISSION UNIT

The present invention relates to hydraulic actuators in general and has specific applications in connection with control of continuously-variable-ratio units ("variators") used in transmissions.

The specific problems which were addressed by the inventors arose in connection with variators of the toroidal-race rolling-traction type and these problems will be considered first of all, although the invention has potential applications in other fields. The general construction of such variators, used typically although not exclusively in vehicle transmissions, is well known. They comprise a pair of races, typically in the form of discs, mounted for rotation about a common axis and each having a part-toroidally shaped surface so that between these surfaces a generally toroidal cavity is defined. Within this cavity, and running upon the part-toroidal surfaces of the races, is at least one roller (more typically two or three rollers are provided). The roller serves to transfer drive from one race to the other and is mounted such that its inclination relative to the races can change, altering the radius of the paths traced by the roller upon the faces and consequently altering the rotational speed of one race relative to the other. In this way a continuously variable drive ratio is provided between the two races. A hydraulic piston/cylinder arrangement acts upon the roller, urging it along a direction generally tangential with respect to the axis of the races. The roller is free to "precess" - i.e. to change its

inclination relative to the races - and the variator geometry is such that as the roller moves back and forth along the tangential direction it also precesses to correspondingly increase/decrease the drive ratio.

As the roller moves back and forth its centre follows an arc of a circle, which is the centre circle of the toroidal cavity. Consequently the angle of a piston rod coupling the piston to the roller's mountings must change slightly during this motion. The hydraulic piston/cylinder arrangement is of double acting type, having working chambers on both sides of the piston. It is necessary to provide a seal where the piston rod emerges from the working chamber and to maintain the integrity of this seal despite angular displacement of the piston rod.

The applicant's granted US Patent 5395292 and its European counterpart, patent number 444086, disclose an arrangement using a flexible sealing gland which is mounted in the cylinder end plate and is capable of limited transverse movement without sealing loss (item 77 in Fig. 4 of these patents). The arrangement does perform its function but creating a really effective seal, suitable for long-lived production versions of the variator, has until now proven problematic.

In accordance with the present invention, there is a hydraulic actuator comprising a cylinder having a cylinder axis, a piston defining two working chambers in the cylinder, the working chambers being connectible to respective hydraulic pressures, and an elongate piston rod which is coupled to the piston and which emerges through an end of the cylinder for connection to a component being actuated, wherein the piston rod is capable of angular displacement about a transverse

axis and a seal against egress of fluid from the cylinder is formed where the piston rod emerges from the cylinder by virtue of a piston-rod sealing arrangement comprising a seal body through which the piston rod passes, a radially inwardly open recess lying around the piston rod and having two walls lying in radial planes with respect to the cylinder axis, between which the seal body is axially located, the seal body being capable of radial movement within the recess in order to accommodate the angular displacement of the piston rod and carrying a sealing band having a first sealing surface which faces radially inwards and a second sealing surface which faces axially, the first sealing surface being resiliently biased against the piston rod and the second sealing surface being resiliently biased against one of the aforementioned walls of the recess, thereby to form a pair of seals which together resist egress of fluid from the end of the cylinder.

Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Fig. 1 is a simplified illustration of major components of a toroidal-race rolling-traction variator of known type;

Fig. 2 is a perspective, partly sectional view of parts of a first hydraulic actuator embodying the present invention;

Fig. 3 is a partly sectional view of a piston road and seal arrangement of a second hydraulic actuator embodying the present invention;

Fig. 4 is a scrap sectional view of a piston for use in an actuator embodying the present invention;

Fig. 5 is an exploded, perspective illustration of a further toroidal-race, rolling-traction variator; and

Fig. 6 is a perspective illustration of a roller/actuator assembly of the Figure 5 variator in which a cylinder is cut-away to show a piston arrangement therewithin.

As noted above, the present invention is particularly applicable to toroidal-race variators. While it has potential application in other quite separate, technical fields, an embodiment of the invention will be described in detail in connection with such a variator, to serve as an example of the invention's implementation and to make clear the advantages made available by virtue of the invention. In the known variator arrangement illustrated in Figure 1, two input discs 12, 14 are mounted upon a drive shaft 16 for rotation therewith and have respective part toroidal surfaces 18, 20 facing toward corresponding part toroidal surfaces 22, 24 formed upon a central output disc 26. Two toroidal cavities are thus formed by opposing surfaces of the input and output discs. The output disc is journalled such as to be rotatable independently of the shaft 16. Drive from an engine or other prime mover, input via the shaft 16 and input discs 12, 14, is transferred to the output disc 26 via a set of rollers disposed in the toroidal cavities. A single representative roller 28 is illustrated but typically three such rollers are provided in both cavities. An end load applied across the input discs 12, 14 by a hydraulic end load arrangement 15 provides contact forces between rollers and discs to enable such transfer of drive. Drive is taken from the output disc to further parts of the transmission, typically an epicyclic mixer, as is well known in the art and described e.g. in UK patent application 8429823. Each

roller is journalled in a respective carriage 30 which is itself coupled to a hydraulic actuator 32 whereby an adjustable translational force can be applied to the roller/carriage combination. As well as being capable of translational motion the roller/carriage combination is able to rotate about an axis determined by the hydraulic actuator 32 to change the "tilt angle" of the roller and to move the contacts between rollers and discs, thereby varying the variator transmission ratio, as is well known to those skilled in the art.

The illustrated variator is of the type known in the art as "torque control". The hydraulic actuator 32 exerts a controlled force on the roller/carriage and for equilibrium this must be balanced by the reaction force upon the roller resulting from the torques transmitted between the disc surfaces 18, 20 , 22, 24 and the roller 28. The axis determined by the actuator 32 is angled to the plane perpendicular to the variator axis. This angle is referred to as the "castor angle". The well known result of this arrangement is that in use each roller automatically moves and precesses as necessary to transmit a torque determined by the biasing force from the actuator 32.The force from the actuator 32 is controlled by means of a hydraulic circuit (not illustrated) through which fluid is supplied to the actuators at variable pressure.

As explained above the centre of the roller follows an arc which is part of a notional circular line which is the centre line of the toroid defined by the discs 12, 14. That is, as piston 36 of the actuator 32 moves along its cylinder 38 the roller follows a curved path. To accommodate this, the angle of a piston rod 40 coupling the roller carriage to the piston 36 must change slightly, relative to the cylinder 38, as the

piston moves. Since the piston 36 is of double acting type, such angular displacement of the piston rod must be accommodated while retaining a seal in region 42 where the piston rod exits the cylinder, in order to enable working chamber 44 to maintain hydraulic pressure.

Figure 1 represents the prior art and details of the required seal arrangement are not shown in that drawing. However in Figure 2 an actuator, incorporating the seal, is shown in more detail.

A cylinder whose wall is seen at 200 receives a piston 202 rigidly coupled to a piston rod 204. The piston seals against the cylinder through a seal received in annular recess 206. A suitable piston seal will be described in more detail below. The construction permits some degree of angular displacement of the piston and its rod (see arrows 208) about axes transverse to the piston rod and also allows rotation of the piston rod about its longitudinal axis (see arrow 210). The piston rod is coupled to a roller carriage of a variator of the general type illustrated in Fig. 1 (but omitted from Fig. 2 for the sake of representational simplicity) and the carriage, with its associated roller, is permitted to move along the curved centre line of its toroidal cavity (due to angular motion as indicated by arrows 208) as well as rotating to vary transmission ratio (arrows 210).

The actuator is of double acting type. That is the piston is urged in opposite directions by pressure in opposed working chambers 212, 214, each connectible to a respective source of hydraulic fluid at controllable pressure.

The seal arrangement at the cylinder end 216 where the piston rod emerges

will now be described. The cylinder 200 has a transverse end wall 218 with a centre opening 220 through which the piston rod emerges, clearance between the piston rod and the end wall in this region allowing the required angular displacement 208. An exterior face of the cylinder end wall bears an axially projecting annular flange 222 with a circumferential shoulder 224 adjacent which is located a closure plate 226 having a centre opening through which the piston rod passes, again with sufficient clearance to permit its required angular displacement. Between the end wall 218 and the closure plate 226 is thus formed an inwardly open annular recess 227 within which a piston-rod seal arrangement is received and located.

The piston-rod seal arrangement comprises an annular seal body 228 located between the end wall 218 and the closure plate 226. Note that there is radial clearance between the seal body's outer face and the inner surface of the flange 222, so that the seal body can move radially to accommodate the angular displacement 208 of the piston rod 202. The piston-rod seal arrangement may thus be described as "floating" in that it is capable of moving with the piston rod. The seal body 228 could be formed of metal but is more preferably a moulded plastics item. The piston rod passes through a centre opening of the seal body and the arrangement must provide a seal against egress of fluid from the working chamber 212 along two possible routes: (1) between the piston rod 204 and the seal body 228 and (2) around the outside of the seal body, through the annular recess 227. The Fig. 2 embodiment utilises a resilient sealing band 230 of generally "L" cross section providing sealing pads 232 and 234 contacting respectively the piston rod 202 and the closure plate

226. To urge the pads into sealing contact, resilient biasing rings 236, 238 are provided in recesses in the seal body 228 and are pre-stressed upon assembly. Note that due to the "L" section of the sealing band 230, any fluid passing between the sealing rings and the sealing band is not permitted to escape.

Slots shown in phantom at 240 and formed in the face of the seal body 228 adjacent the cylinder end wall 218 allow hydraulic fluid to enter the recess 227, lubricating the seal arrangement and so minimising any wear resulting from its radial motion.

It will be appreciated that the working area of piston face 242 from which the piston rod 204 emerges is less than the working area of the opposite piston face 244 by the cross sectional area of the piston rod. This has not proven problematic in practice.

Fig. 3 illustrates an alternative floating piston-rod-seal arrangement. The cylinder end wall is seen at 218, the closure plate at 226 and the piston rod at 204. The piston-rod seal arrangement here comprises a seal body 300 of "J" section receiving a pre-stressed biasing ring 302 which acts on an "L" section resilient sealing band 304, urging it both axially, against the cylinder end wall 218, and radially, against the piston rod 204. In this way the two required seals are formed.

It was mentioned above that the piston 202 is capable of some angular movement in its cylinder. Fig. 4 illustrates one possible way of allowing for this movement while retaining the required seal between cylinder and piston. An outwardly facing annular recess in the piston 202 itself receives a wear ring 306

relieved at 308, 310 and so capable of angular movement as again indicated by arrows 208. Such angular piston movement is sometimes referred to as "swashing". The wear ring 306 itself has an outwardly facing recess receiving at its base a sealing ring 312 which radially outwardly urges a piston seal 314 through which the piston seals against the cylinder.

The piston rod need not necessarily be coupled directly to the roller's mountings. Figures 5 and 6 illustrate an alternative variator construction in which each piston is instead coupled to the mountings of a respective roller through a respective lever. In Figure 5 the variator races are seen at 500, 502, 504. There are 6 roller / piston assemblies 506A-F each comprising a roller 508 mounted in a carriage 510 coupled by a universal joint 512 (formed in this embodiment as a ball and socket joint) to a lever 514. The lever is in each case pivotally mounted about a transverse bore 516 therein and pivotally coupled at 518 to a piston rod 520 of a piston 522. Each piston moves along a direction which is vertical in the drawing, but the levers cause the rollers to move along the required tangential paths in response. Note that to provide the necessary motion and positioning of the rollers, three different types of lever are required. Various components of the variator are omitted from Figure 5 for the sake of simplicity and clarity. These include the cylinders in which the pistons run, and also the shaft upon which the races 500, 502, 504 are mounted.

As in the previously described variator construction, it is necessary to accommodate angular motion of the piston rods while maintaining integrity of the

seal where the piston rods emerge from the cylinder. In Figure 6 the cylinder 524 is seen and a seal arrangement 526 is provided which is identical to the seal arrangement already described with reference to Figure 2.

It is to be understood that the above described embodiments are presented as examples only of actuators embodying the present invention: numerous possible variations will present themselves to the skilled person. One constructional alternative would be to use, in place of a "swashing" piston, an articulated joint such as a ball and socket joint between the piston and the piston rod. Furthermore while the present invention is ideally suited to use in variators, it is considered that it is also applicable to hydraulic actuators used in other fields of technology.

CLAIMS

1. A hydraulic actuator comprising a cylinder having a cylinder axis, a piston defining two working chambers in the cylinder, the working chambers being connectible to respective hydraulic pressures, and an elongate piston rod which is coupled to the piston and which emerges through an end of the cylinder for connection to a component being actuated, wherein the piston rod is capable of angular displacement about a transverse axis and a seal against egress of fluid from the cylinder is formed where the piston rod emerges from the cylinder by virtue of a piston-rod sealing arrangement comprising a seal body through which the piston rod passes, a radially inwardly open recess lying around the piston rod and having two walls lying in radial planes with respect to the cylinder axis, between which the seal body is axially located, the seal body being capable of radial movement within the recess in order to accommodate the angular displacement of the piston rod and carrying a sealing band having a first sealing surface which faces radially inwards and a second sealing surface which faces axially, the first sealing surface being resiliently biased against the piston rod and the second sealing surface being resiliently biased against one of the aforementioned walls of the recess, thereby to form a pair of seals which together resist egress of fluid from the end of the cylinder.

2. A hydraulic actuator as claimed in claim 1, wherein the sealing band comprises, in cross section, a substantially axially extending limb carrying the second seal surface and a substantially radially extending limb carrying the first sealing surface.

3. A hydraulic actuator as claimed in claim 2, wherein the sealing band has an "L" shaped cross section.

4. A hydraulic actuator as claimed in claim 2 or claim 3 wherein the axially extending limb projects from the remainder of the sealing band in a direction toward the working chambers.

5. A hydraulic actuator as claimed in any preceding claim further comprising resilient biasing means pre-stressed between the seal body and the sealing band to urge the first and second sealing surfaces respectively against the piston rod and the aforementioned wall.

6. A hydraulic actuator as claimed in any preceding claim wherein the resilient biasing means comprises at least one biasing ring of resilient material.

7. A hydraulic actuator as claimed in claim 6 wherein the biasing ring is received in an annular recess in the seal body.

8. A hydraulic actuator as claimed in claim 6 or claim 7 comprising two biasing rings acting on the first and second sealing surfaces.

9. A hydraulic actuator as claimed in any preceding claim wherein the seal body has at least one recess or passage providing a route for entry of fluid to the annular recess in which the seal body is located, thereby to lubricate the second sealing surface.

10. A hydraulic actuator as claimed in any preceding claim wherein the seal body is rigid.

11. A hydraulic actuator as claimed in any preceding claim wherein the

aforementioned walls defining the annular recess are carried by the cylinder.

12. A hydraulic actuator as claimed in claim 11 wherein one of the walls of the annular recess is an end wall of the cylinder, an axially projecting flange being formed on the cylinder end wall which receives a separately formed plate forming the other of the walls of the annular recess.

13. A continuously variable ratio transmission unit comprising a hydraulic actuator as claimed in any preceding claim.

14. A continuously variable ratio transmission unit as claimed in claim 13 wherein drive is transmitted at variable ratio between a pair of races by at least on movably mounted roller, the piston rod being operatively coupled to the roller.

15. A continuously variable transmission unit as claims in claim 14 wherein the piston rod is coupled to the roller through a lever.

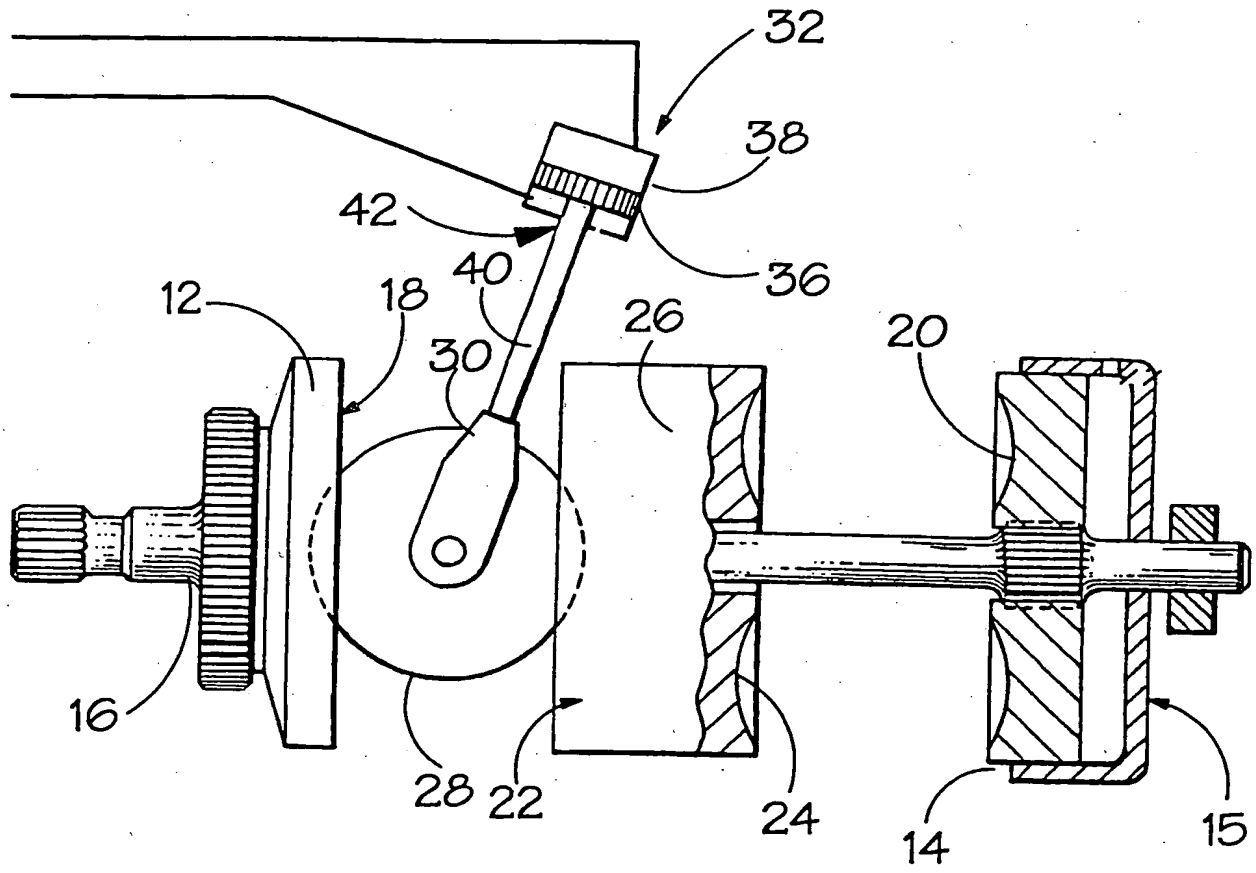

FIG.1.

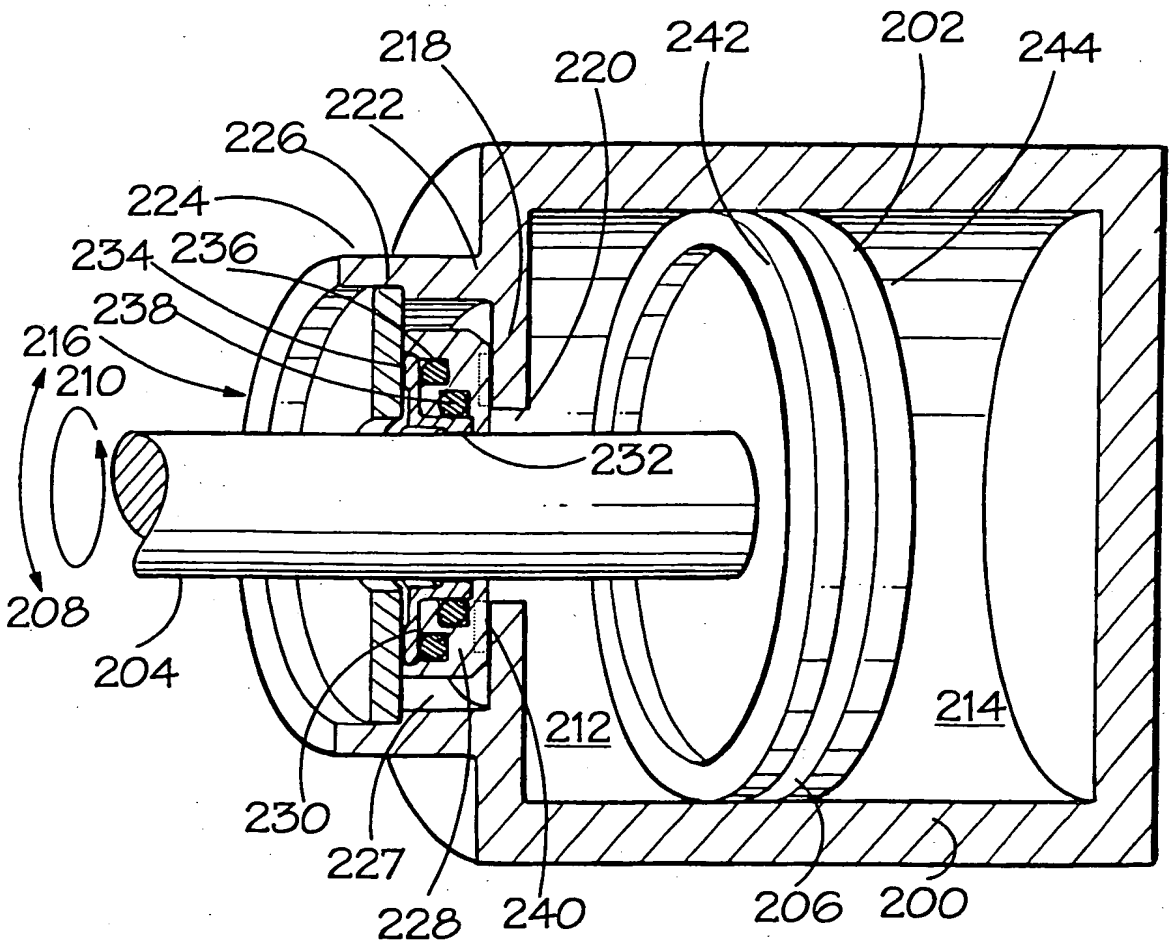
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FIG.2.

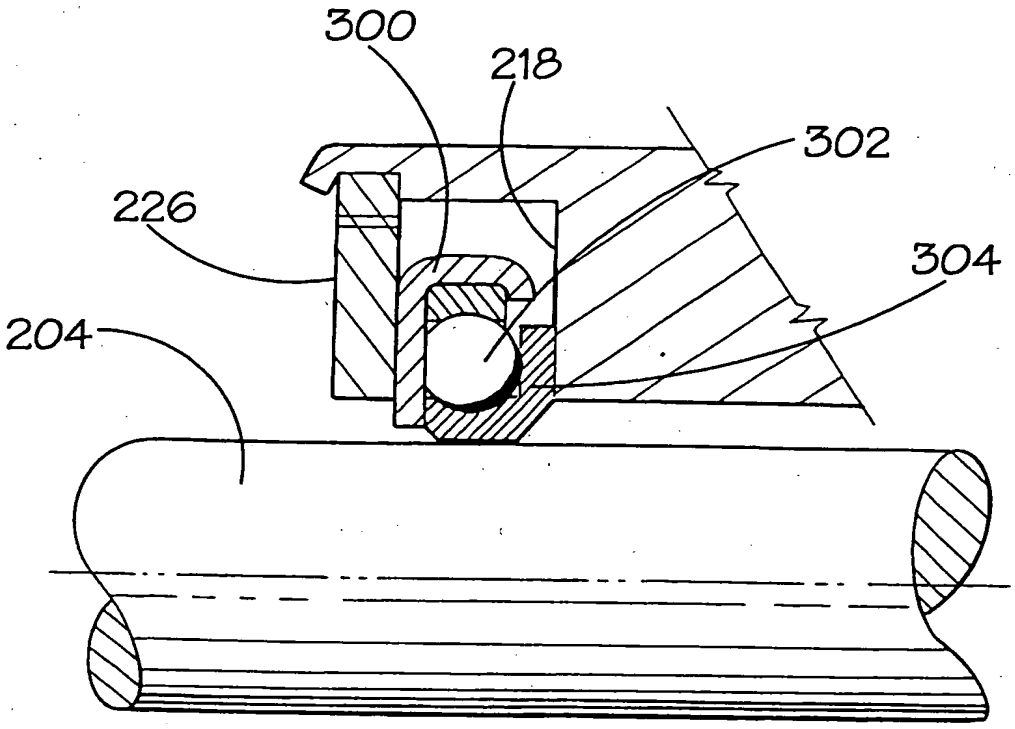

FIG.3.

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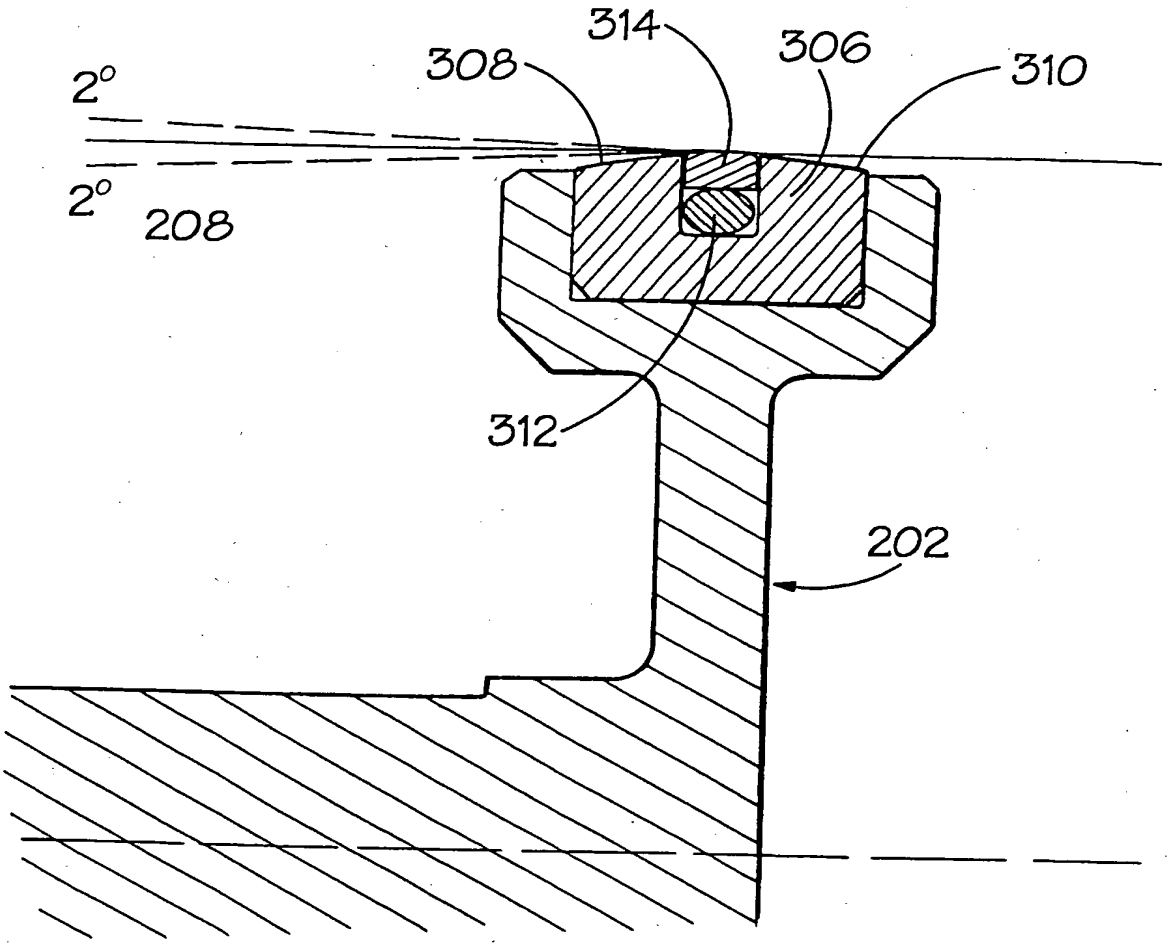

FIG.4.

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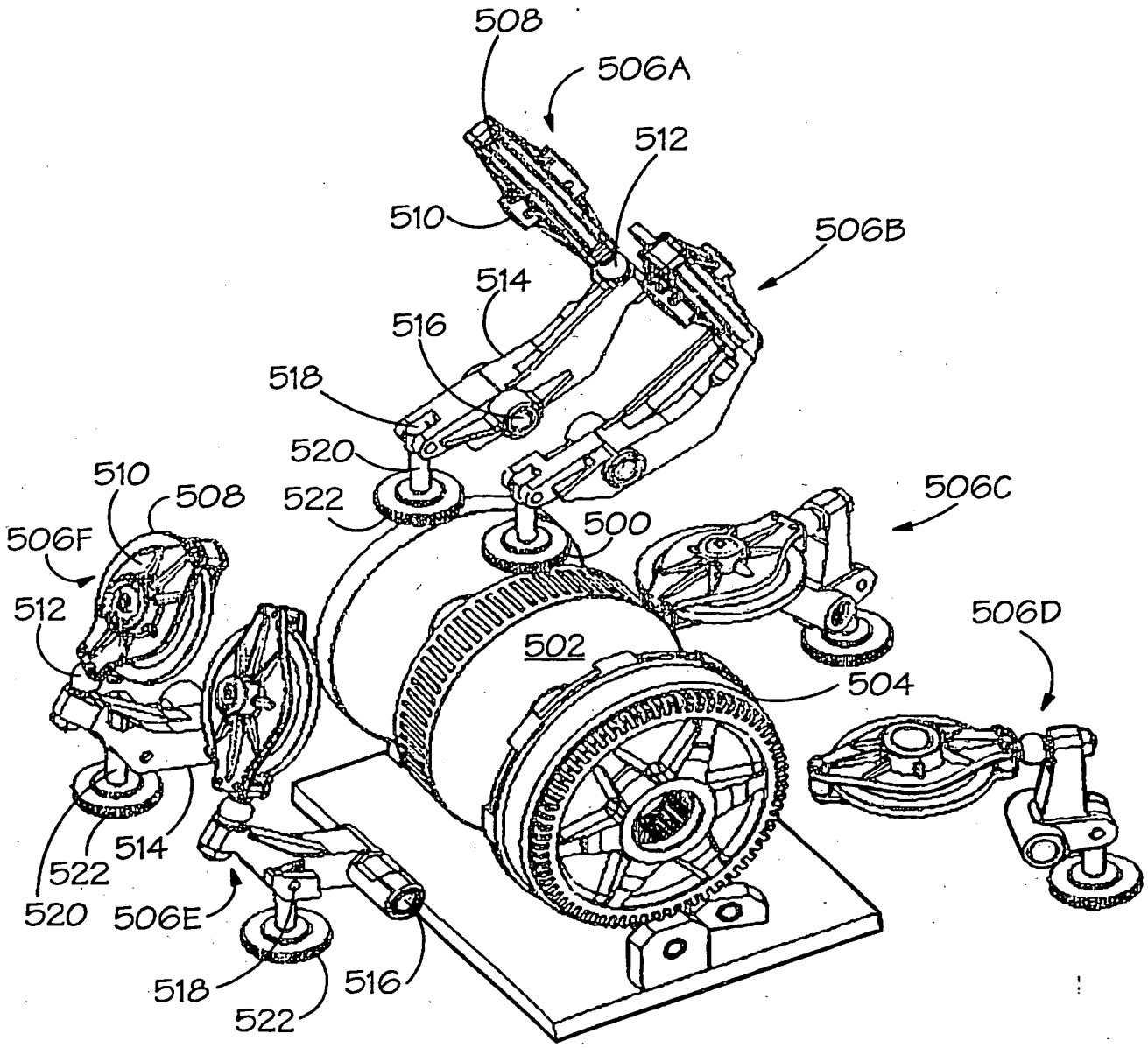

FIG.5.

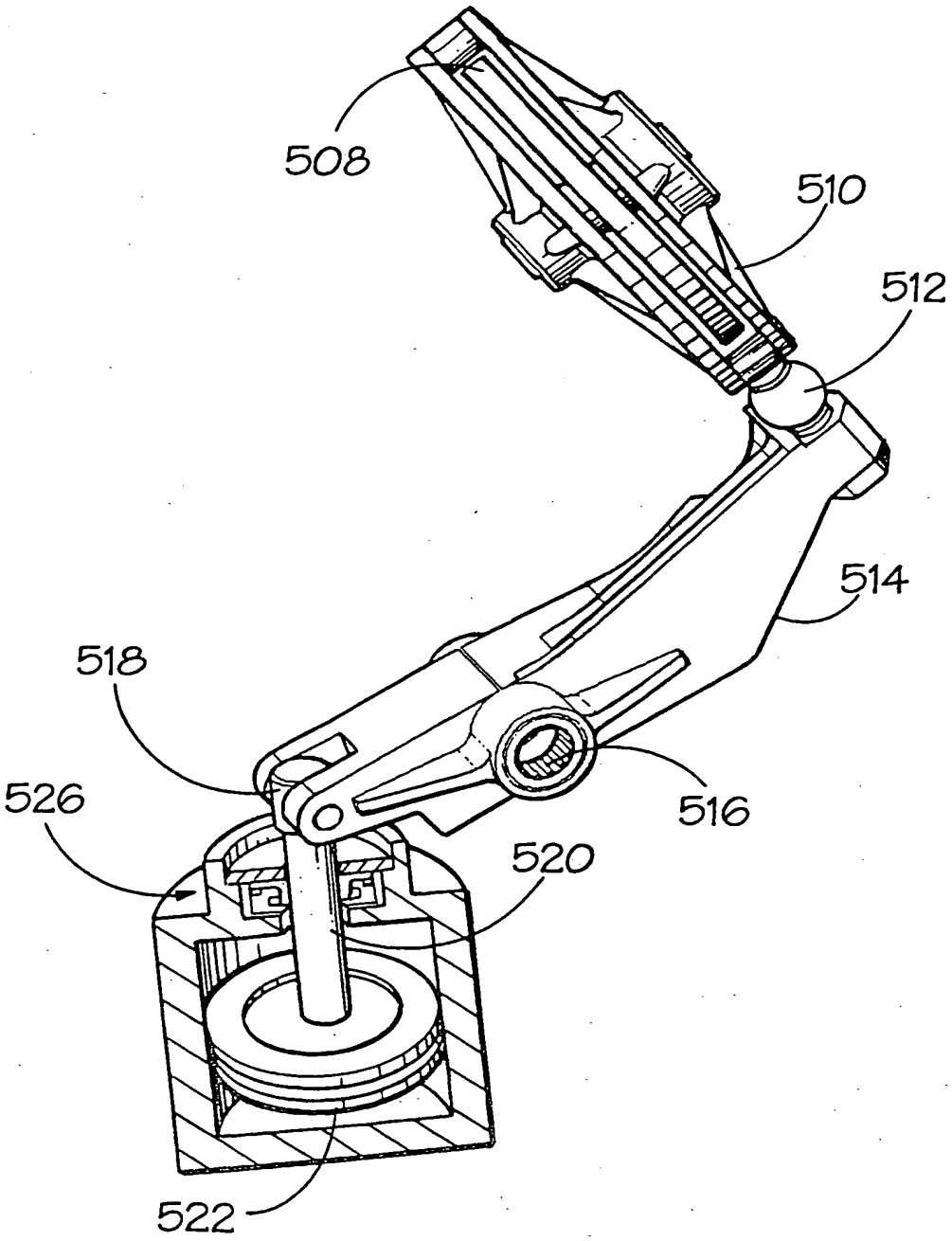

FIG.6.

INTERNATIONAL SEARCH REPORT

Internati pplication No
PCT/GB 03/03326

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F16J15/32 F16H61/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F16J F16H F15B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
27 October 2003	04/11/2003

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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